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BORON AND ITS COMPOUNDS

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R. M. SANTMYERS

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

BORON AND ITS COMPOUNDS[1]

By R. M. Santmyers[2]

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[1] - The Bureau of Mines will welcome reprinting of this article, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6499."

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INTRODUCTION

The chief compounds of boron are borax and boric acid, both of which have important applications in industry.

At present the United States furnishes more than half of the world's requirements of borate materials, practically all from California. Nearly the entire production of borax in this country is under the control of four companies: The American Potash and Chemical Corporation, the Pacific Coast Borax Co., the West End Chemical Co., and the Western Borax Co.

The Pacific Coast Borax Co. is reported as being financially controlled by Borax Consolidated (Ltd.), a British company which also owns or finances borax properties and plants in Chile, Peru, Bolivia, and Asia Minor (Turkey). In Argentina the output is controlled by the Belgian International Co.

The increasing use of borax and boric acid is due in a large measure to the research activities of the principal producing companies. The discovery of rasorite in 1926, making available almost unlimited amounts of borax and thereby tending to reduce prices, spurred producers to even greater activity in securing new markets for their expanding output. The net result of these new developments has been to strengthen the export position of the United States.

ACKNOWLEDGMENT

The assistance of K. G. Warner, U. S. Bureau of Mines, who compiled the statistical data, is gratefully acknowledged.

GENERAL DESCRIPTION

Boron, a nonmetallic element (No. 5) heads the third column in the periodic chart of the atoms. The atomic weight (1930) is 10.82. The specific gravity has not been definitely determined, as the samples tested have been more or less impure, but it appears to exceed 1.84. Boron occurs in two forms, amorphous and crystalline.

Amorphous boron is produced by the action of potassium on boric acid; the resulting powder is greenish brown, and is tasteless and odorless. It is a nonconductor of electricity, very infusible, insoluble or possibly slightly soluble in water, insoluble in alcohol, ether, and solutions of caustic alkalies, and is nonmetallic in its reactions.[3] Strong nitric acid will dissolve it when cold and hot sulphuric acid will attack it. Owing to its finely divided condition when produced, it is apt to take fire spontaneously; but if consolidated by pressure, it is not affected by air at ordinary temperatures, though it burns with a reddish light when heated. It is one of the few substances that

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3 - Segerblom, W., Properties of Inorganic Substances: New York, 1927, p. 162.

will combine directly with nitrogen, which it does when heated in that gas.

Amorphous boron is soluble in melted aluminum, from which it crystallizes out on cooling. The crystals so obtained were formerly thought to consist of pure boron, but it has been shown that they always contain a definite amount of aluminum.

This crystalline boron is a black solid having a specific gravity of 2.34 to 2.64. It is almost as hard as diamond and only inferior to it in toughness and strength. The crystals will scratch both corundum and ruby. J. R. Rydberg places the hardness as 9.5 on his scale.[4] They melt at about 2,000° C., and have a sensible vapor tension at 1,600° C. They rapidly increase in electrical conductivity when heated.

OCCURRENCE

Boron is not a particularly rare element. Workable deposits of boron minerals are quite uncommon, but the element is widely distributed in small amounts. According to Clarke, the 10-mile crust, the hydrosphere and the atmosphere of the earth contain 0.001 per cent of boron.[5]

In nature, boron is never found in the uncombined or elementary state. The element occurs in the form of boric acid and borates, especially in regions that are or have been volcanic. It is also an essential constituent in many silicate minerals, including tourmaline, dactolite, etc.

Borax and the borates deposits occur in at least five distinct forms, all of which at one time or another have served as sources of borax.[6]

1.--Old Lake Beds.--In deposits found in old lake beds, borates, chiefly colemanite, occur in bedded deposits with other sedimentaries, such as gypsum, limestone, and shales. The origin of deposits of this type is generally ascribed to the action of boric acid solutions or vapors, resulting from volcanic activity, upon beds of limestone or gypsum. Examples: The colemanite deposits of Death Valley and elsewhere in the Great Basin of California and of the Muddy Mountains district of Nevada; the Turkish deposits of pandermite near Panderma, Asia Minor.

With the discovery of rasorite (kernite) in the Kramer borate district, considerable interest was expressed as to its origin.

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[4] - Rydberg, J. R., Die Härte der einfachen Körper: Ztschr. Phys. Chem., vol. 33, 1900, p. 353.

[5] - Clarke, F. W., Data of Geochemistry: U. S. Geol. Survey, Bull. 770, 1924, p. 29.

[6] - Ladoo, R. B., Non-Metallic Minerals, Occurrence, Preparation, Utilization: New York, 1925, pp. 101-2.

According to W. T. Schaller:[7]

> A borax lake formerly occupied the area of the Kramer borate district. By evaporation of the water, borax crystallized out. Borax crystals may have been concentrated at the east side by wind, or there may have been a local depression at the east side into which the concentrated borax solution flowed, leaving only a relatively minor quantity of borax at the west end. This borax was covered by mud and clay, with probably layers of volcanic ash. On top of this borax-bearing clay was deposited additional clay, also containing borates, more probably ulexite. This clay bed would correspond to the borate clays of the west end of the district. On top is the borate-free valley fill (sand and gravel). Heat from some source--the igneous rock if intrusive--melted the buried borax deposit in its own water of crystallization, a temperature of about 150° being reached. Enough of the water was driven off so that on cooling the 4-hydrate crystallized as kernite. Locally, where the escape of water was prevented by impervious clay, the fused borax solidified into massive borax. The excess of water driven off from the fused borax entered the overlying ulexite-carrying clay and recrystallized the original 'cotton ball' ulexite into the fibrous veins now found.

2.--Borax Marshes or Dry Lakes.--The borax marsh deposits of California, Nevada, and Oregon consist chiefly of ulexite but also contain borax (tincal). The borates were probably derived by the leaching of colemanite deposits at a higher elevation. The ulexite deposits of the lagoons and "salares" of Ascotan in the Atacama district of Chile and elsewhere in Chile, Peru, Bolivia, and Argentina are probably of similar origin. The borax (tincal) of Tibet is derived from salt lakes, which probably obtained their borax content from volcanic sources.

3.--Volcanic Vapors.--The fumaroles, soffione, or gaseous emanations of Tuscany, Italy, contain boric acid (sassolite), which is recovered commercially by solution in water.

4.--Hot Springs in Volcanic Regions.--Hot springs in Tuscany, Italy, contain sassolite. Hot springs deposit colemanite in Chile, at Baños del Toro; and borax (tincal) in California, Nevada, and the Puga Valley of Ladakh, Kashmir, India. Mud volcanoes of Kertch and Taman, southern Russia, also deposit borax.

5.--Marine Borates.--The complex salt deposits of the Stassfurt district of Germany, regarded as of marine origin, contain boracite.

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[7] Schaller, W. T., Borate Minerals from the Kramer District, Mohave Desert, California: I, U. S. Geol. Survey, Prof. Paper 158, 1929, p. 167.

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Boron Minerals

The principal natural compounds of boron are crude borax or tincal (California, tincalconite), boracite, boronatrocalcite (ulexite), colemanite, rasorite (kernite), kramerite, pandermite (colemanite from Asia Minor), and sassolite (boric acid from Italy).

Other boron minerals such as hydroboracite, rhodizite, borocalcite, and botryolite have little or no commercial value. Small quantities of boron are found in schorl, apyrite, and axinite, while minute amounts are contained in certain mineral waters; in sea water; in certain plant ashes; and in some animal tissues.

Borax (Tincal)

Composition.--Borax is sodium tetraborate ($Na_2B_4O_7.10H_2O$, or $Na_2O.2B_2O_3.10H_2O$):-B_2O_3, 36.6 per cent; Na_2O, 16.2 per cent; H_2O, 47.2 per cent.

General Description.--Borax occurs as short, stout, white monoclinic prisms, in solution in saline lakes and as a glistening white efflorescence or constituent of certain alkali soils.

Physical Properties.--Hardness, 2.0 to 2.5. Specific gravity, 1.69 to 1.72. Melting point, at 1 to 1.5 in scale. Index of refraction, 1.447 to 1.472. Color, white to grayish, greenish or bluish. Streak, white. Luster, vitreous to dull. Transparency, translucent to opaque. Tenacity, brittle. Readily soluble in water. Sweetish, alkaline taste. Crystals effloresce, losing $5H_2O$ below 100° C., sixth molecule of H_2O at 100° C., seventh and eighth molecules at 130° C., ninth at 150° C., and tenth, at 160° C., or above; 300° necessary to insure complete desiccation.

Boracite (Stassfurtite)

Composition.--Boracite is magnesium borate and chloride ($Mg_7Cl_2B_{16}O_{30}$ or $6MgO.8B_2O_3.MgCl_2$):-B_2O_3, 62.37 per cent; MgO, 27.00 per cent; $MgCl_2$, 10.63 per cent.

General Description.--Boracite occurs in small, hard, glassy isometric crystals, or in white, rather soft masses (stassfurtite variety).

Physical Properties.--Hardness, 7 (crystals); 4.5 (masses). Specific gravity, 2.9 to 3. Melting point, 2 in scale. Index of refraction, 1.662 to 1.673. Color, white to yellowish or greenish. Streak, white. Luster, vitreous. Transparency, transparent to opaque. Tenacity, brittle.

Ulexite (Boronatrocalcite)

Composition.--Ulexite is a borate of sodium and calcium ($CaNaB_5O_9 \cdot 8H_2O$, or $2CaO.Na_2O.5B_2O_3.16H_2O$):- B_2O_3, 43.0 per cent; CaO, 13.8 per cent; Na_2O, 7.7 per cent; H_2O, 35.5 per cent.

General Description.--Ulexite occurs in white, rounded masses ("cotton balls"), composed of loosely compacted, fine, silky fibers, easily pulverized between the fingers.

Physical Properties.--Hardness, 1. Specific gravity, 1.65. Melting point, at 1 in scale of fusibility with intumescence. Index of refraction, 1.491 to 1.520. Color, white. Streak, white. Luster, silky. Cleavag fibrous. Transparency, translucent. Tenacity, brittle. Insoluble in cold water; slightly soluble in hot water; soluble in acids.

Colemanite

Composition.--Colemanite is calcium borate ($Ca_2B_6O_{11} \cdot 5H_2O$ or $2CaO \cdot 3B_2O_3 \cdot 5H_2O$):-$B_2O_3$, 50.9 per cent; CaO, 27.2 per cent; H_2O, 21.9 per cent.

General Description.--Colemanite occurs in short, prismatic white crystals (resembling datolite); in loosely compacted, white, chalky masses; and in firm, white, compact, porcelain-like masses.

Some authorities consider priceite as merely the chalky variety of colemanite, and pandermite as the hard, compact variety of colemanite. Other authorities regard colemanite as a distinct mineral, and priceite and pandermite are synonomous terms for a mineral having the formula $5CaO.6B_2O_3.9H_2O$ (Hardness, 3. Specific gravity, 2.4. Index of refraction, 1.572 to 1.594). Still others regard all three as separate and distinct minerals. Thus, priceite is assigned the formula $3CaO.4B_2O_3.6H_2O$. (Hardness, 3. Specific gravity 2.26 to 2.48); and pandermite the formula $8CaO.10B_2O_3.15H_2O$.

Physical Properties.--Hardness, 3.5 to 4.5. Specific gravity, 2.26 to 2.48. Melting point, at 1.5 in scale of fusibility. Index of refraction, 1.586 to 1.614. Color, white or colorless. Streak, white. Luster, vitreous to dull. Cleavage, perfect clinopinacoidal. Fracture, uneven to subconchoidal. Transparency, transparent to opaque. Tenacity, brittle. Decrepitates, intumesces, and fuses easily on heating. Insoluble, in water. Easily soluble in hot hydrochloric acid.

Rasorite

Composition.--Kernite is a borate of sodium, ($Na_2B_4O_7 \cdot 4H_2O$), containing theoretically 51.02 per cent of boric acid, 22.66 per cent of sodium oxide and 26.32 per cent of water and organic matter.

General Description.--Rasorite occurs in monoclinic crystals which closely approach triagonal forms. The crystals reach a size of several feet in diameter and are buried in mud or in other borate minerals (tincal). Rasorite has such a perfect cleavage in two directions that it cleaves in splintery forms which give one the impression of columnar or needle-like crystals.

Physical Properties.--The hardness of rasorite is 2 1/2 but varies slightly on the different faces and in different directions. Specific gravity, 1.908. It is colorless and transparent. Luster is vitreous, but on a fibrous cleavage surface it is slightly satiny. The streak is white.

Sassolite (Natural Boric Acid)

Composition.--Sassolite is boric acid, (H_3BO_3):-B_2O_3, 56.4 per cent; H_2O, 43.6 per cent.

General Description.--Sassolite occurs chiefly in solution or in vapors near volcanoes or hot springs; also in small white or yellowish scales.

Physical Properties.--Hardness, 1. Specific gravity, 1.43. Melting point, at 0.5 in scale. Index of refraction, 1.340 to 1.459. Color, white or yellowish. Streak, white. Luster, pearly. Transparency, translucent. Tenacity, brittle. Readily soluble in water. Sour or acid taste.

The following analyses show the composition of the more important commercial borates:-

Composition of commercial borates, per cent

	Rasorite, California	Colemanite, California	Ulexite, Chile and Peru	Boracite, Pandermite Asia Minor
Boric acid	51.02	40.19	44.38	45.89
Lime	0	31.89	16.14	30.62
Magnesia	--	1.50	.91	0.53
Oxides of iron and alumimum	--	0.62	.48	0.98
Sodium oxide	22.66	--	6.50	--
Sodium chloride	--	--	7.46	--
Carbon dioxide	--	8.53	--	--
Sulphur trioxide	--	0.26	3.35	1.25
Water and organic matter	26.32	5.83	16.25	17.09
Insoluble matter	0	11.18	4.71	3.64
	100.00	100.00	100.18	100.00

HISTORY

Under the name of tincal or tincar, crude borax was exported to Europe from Central Asia, through Constantinople and Venice.[8] It is not known when the trade began, but it must have been before G. Agricola, 1556, since borax was much used in his time. The Arabian Avicenna first described tincar. From the descriptions in "De natura fossilium," by Agricola, it is evident that his "chrysocolla which the Moors call borras" was the same salt now called borax. According to Hoefer's "Histoire de la chimie" (1842) the word borax is derived from an Arabian or Persian word "borak" meaning white.

After considerable discussion as to the identification of the different salts which at one time or another had been called borax, the true nature of the substance became clear; "sal sedativum" was recognized as an acid and called boric or boracic acid. In August, 1807, Sir Humphry Davy electrolyzed moist boric acid and obtained a dark-colored combustible mass at the negative pole. The following year Davy in England and J. L. Gay-Lussac and L. J. Thenard in France again isolated the same substance, Davy by heating potassium with boric acid in a gold tube. Gay-Lussac and Thenard prepared the substance by heating boric acid (boron trioxide) very strongly until all of its water was expelled and then heating the resulting substance (now known as boric acid) with metallic potassium in an iron tube. The potassium removed the oxygen from the boric acid, setting the element free. Davy proposed the name "boron" for this new element.

BORAX

Description

The most important derivative of the element boron is borax, or sodium tetraborate ($Na_2B_4O_7.10H_2O$). It consists of 36.6 per cent of boron tetroxide or anhydrous boric acid (B_2O_3), 16.2 per cent of soda (Na_2O) and 47.2 per cent of water (H_2O). It is a white powder similar in appearance to boric acid, is readily soluble in water and gives a faintly alkaline solution.

Borax occurs in nature both as a saline efflorescence on the soil and as monoclinic crystals, sometimes of considerable size.

USES

In industry, borax has a considerable number of extremely important applications. Borax is so easily fusible that it is of great value as a flux. Upon this property, in part at least, depends the use of borax in the manufacture of enamels for iron and steel articles, such as bathtubs, kitchen and bath fixtures, cooking utensils and laboratory equipment; in making borosilicate glasses (of the "Pyrex" type) such as is used for making baking dishes, laboratory glass ware, lamp chimneys, and electric-lamp bulbs; in pottery glazes; in smelting precious metal concentrates; in assaying, soldering and welding of metals; and in brass smelting.[9]

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[8] - Mellor, J. W., Inorganic and Theoretical Chemistry: Vol. 5, London, 1924, pp. 1-3.

In addition to lowering the melting point, the value of borax in glass depends upon the following properties: (1) boron compounds impart a high refractiveness; (2) they reduce the tendency to devitrification; and (3) they lower the coefficient of expansion.

For the manufacture of certain types of borax glass, colemanite in its natural form is used.

Borax is used in considerable quantities in the laundry and kitchen. In those localities where the water is highly mineralized or is of the quality known as "hard water," borax is used extensively as a water softener and by reacting with the soap-destroying constituents of hard water it effects a saving of soap. Borax is a constituent of certain high-gloss starches and is similarly used in paper mills for imparting a gloss to book paper and playing cards. Hat makers prepare a size for stiffening hats by dissolving shellac in a solution of borax.

Borax is used by the citrus industry as a preservative. Lemons dipped in a 5 per cent solution of borax at 115° F. for five minutes keep in excellent condition for periods longer than a month in an ordinary shed.[10] It is also found to act as a preservative for wood. Added to rubber latex to the amount of 1.2 to 1.5 grams per liter, it acts as an anticoagulent. A dilute solution (3 g. p. l.) acts as a preservative and retards the rate of vulcanization when kept as long as two weeks, after which it increases the rate.

One of the important commercial uses for borax as well as boric acid is in the tanning industry. Here it has a wide application in the soaking and cleaning of hides and dressing the leather for subsequent processes of manufacture. It is also used in the washing and bleaching of chrome leather preparatory to dyeing and as a mordant in applying certain colors to leather.

In the textile industry borax is used in dyeing and as a means of rendering certain cloths fireproof. It is used as one of the reagents in the chemical degumming of silk.

Borax is valuable as a flux for welding and brazing metals. This use depends upon its property of easily dissolving the metallic oxides, thus leaving a clean and smooth surface for welding.

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9 - Ladoo, R. B., Non-Metallic Minerals, Occurrence, Preparation and Utilization: New York, 1925, p. 109.

10 - Manning, Paul D. V., Borax: Mineral Industry during 1929, New York, vol. 38, 1930, p. 66.

Borax is an effective larvicide and is particularly recommended for the destruction of fly larvae in manures, where it is essential that the larvicide exert no permanent injury on the bacteria which increase the fertilizer value of the manure.[11]

In the chemical industry borax is used for the manufacture of certain chemicals, notably boric acid.

Considerable research has been carried on by the borax producing companies themselves with the idea of increasing the uses of this substance. Prominent among the latest developments is the employment of borax as an ingredient of the batch for container glass. Hitherto the most economical operation of automatic machines for producing glass containers has depended on the use of highly alkaline glass which lacks durability and is subject to chemical change due to weathering. Large-scale production has now proved that in addition to producing a glass having higher durability and one that does not change chemically due to weathering, the time needed to melt and fine the batch is reduced, the yield of workable glass is greater, a higher percentage of marketable containers is obtained, and the output of the machines can be speeded up.[12]

Sources of Supply

Crude borate minerals are mined in a number of countries. These countries are in the order of their importance, the United States, Chile, Turkey, Italy (boric acid), Argentina, Peru, and Germany (see Table 1).

In the United States, up until several years ago, the commercial sources of boron derivatives were almost entirely from colemanite, which is the hydrous borate of calcium ($Ca_2B_6O_{11}.5H_2O$) and to a lesser extent, ulexite, which is the hydrous borate of calcium and sodium ($NaCaB_5O_9.8H_2O$).[13] Some crude natural borax, known as tincal has been mined and quite a large amount of borax is now being produced from natural brines as a by-product of the potash industry at Searles Lake, Calif.

Most of the principal deposits of colemanite and ulexite in the United States are found in Inyo County, Calif., and Churchill County, Nev., and prior to the discovery of rasorite these minerals, together with the brines from Searles Lake, furnished the domestic requirements for borax and boric acid.

Some years ago during the search for potash the value of the Searles Lake deposits became apparent and after considerable research an economical process was formulated for the production of both potash and borax.[14] It is

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11 - Cook, F.C., and Hutchins, R.H., Experiments in the Destruction of Fly Larvae in Horse Manure: Bull. 118, U.S. Dept. of Agriculture, 1914, 24 pp.

12 - Chemistry and Industry, Developments in Boron Products: Vol. 48, No. 49, July 19, 1929, p. 717.

13 - Manning, Paul D.V., Work cited, p. 67.

14 - Teeple, John E., The Industrial Development of Searles Lake Brines: New York, 1929, 182 pp.

probable that competition of this by-product borax forced the opening of the new borax deposits near Amargo, Kern County, Calif., 30 miles east of Mojave, during the latter part of 1926. The deposit is a pure borate of sodium, similar to borax but having only 4 molecules of water of crystallization, $Na_2B_4O_7.4H_2O$. This mineral when first discovered was named "rasorite" but is also known as kernite, named after Kern County, Calif., in which it was first discovered.

Preparation

Borax has been produced from several minerals each requiring somewhat different methods of preparation, but on the whole, the processes are always essentially simple.

From 1864 to about 1873, natural crude borax in the form of impure crystals was taken from the mud on the bottom of two small lakes in Lake County, Calif. These crystals were treated with hot water to separate the soluble borax from the insoluble earthy materials and the borax recovered by recrystallization.[15]

With the discovery of colemanite and ulexite, the production of borax from lake mud crystals ceased. The crude mineral was first calcined, which has the effect of changing the colemanite into a fine powder without affecting the other minerals present.

The finely powdered colemanite may then be readily separated from the other minerals by mechanical means. The colemanite is boiled with a solution of soda, thus forming a solution of borax and an insoluble residue of calcium carbonate. The solution is then filtered and the borax recovered by crystallization.

The preparation of refined borax from rasorite is not as simple as it might appear, for the material dissolves very slowly in water. The mineral is generally calcined in a rotary kiln under superatmospheric pressure to a temperature substantially above 212° F. so that the borax dissolves in its own water of crystallization. This process is also suitable for other borate minerals containing a gangue which has a tendency to slime when treated with water. The solution is separated from the residue and cooled to crystallize the borax.

World Production

The production and consumption of borate minerals have increased rapidly in recent years. The United States is by far the largest source of these minerals, with Chile, formerly of equal importance, now ranking a remote second, with only about 12 per cent of the American output. Turkey is third and Italy fourth.

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15 - Yale, C.G., and Gale, H.S., Borax: Mineral Resources of the United States, U.S. Geol. Survey, 1914, Part II, Nonmetals, pp. 285-6.

Table 1 shows the production of borate minerals in the principal producing countries of the world.

As the United States production and exports have increased, foreign production of borax has constantly decreased. Production of ulexite in Chile, all of which is in the hands of Borax Consolidated, one of the leading operator in the United States, has fallen off about 50 per cent during the past five or six years. It has been stated that the richer deposits in Chile as well as in Bolivia and Peru have been about worked out, and the lower-grade deposits would have difficulty in competing with the rasorite from the United States. In the early part of 1929 a fairly large quantity of borate mineral was produced in Asia Minor but production dropped off sharply in 1930. German production of boracite has always been relatively small and in recent years it has fallen to less than 100 tons annually.

Domestic Production

Crude Borax

Table 2 shows the production of crude borate minerals in the United States for the years 1864 to 1902, inclusive.

Production of borax in the United States began about 1864 and consisted of natural borax crystals which were found in California in the muds on the bottom of two small lakes in Lake County. These crystals were purified by washing, solution, and recrystallization. The product in the early stages of the industry was, therefore, reported as refined material and valued at 28 to 3 cents a pound.

In the late seventies came the development of native borax and of the mineral ulexite ("cotton ball" or boronatrocalcite) from marsh deposits in Nevada and California, which resulted in lowering considerably the price of the refined product. In the statistics, published at that time production was reported as refined borax, as this was the product shipped from the mines.

In 1873 a group of miners on the east side of Searles Lake, then known as Slate Range Lake organized the Borax Lake mining district and the lake then became known as Borax Lake.

Five years later, John W. Searles incorporated the miners on the west side of the lake into the San Bernardino Borax Mining Co. and production increased considerably. In 1895 this company was sold to the Pacific Coast Borax Co. and operations ceased on Searles Lake because the latter company preferred to derive their borax from the colemanite deposits in Death Valley and elsewhere While activities on Searles Lake began again in 1908, actual production on a large scale was not undertaken until in 1916, and borax has been produced there since that date as a by-product of potash.

Table 1.- The world's production of borax and borates, 1900-1930, metric tons[1]

	Calcium borate (Colemanite	Boronatrocalcite (ulexite)			Magnesium borate and chloride (boracite)			Boric acid crude	Boracite[2]	Borax crude[3] (tincal)
ear	United States	Chile	Bolivia	Peru	Argentina	Prussia	German Empire	Italy	Turkey	India
900	23,439	13,177	-----	7,080	-------	217	232	2,491	--------	224
901	21,075	11,547	3,065	4,156	-------	164	184	2,558	4/	162
902	18,148	14,327	593	5,055	-------	172	196	2,763	4/	---
903	31,235	16,879	1,206	2,466	-------	135	159	2,583	4/	---
904	41,411	16,733	1,196	2,675	-------	115	135	2,624	4/	271
905	42,034	19,612	2,146	1,954	-------	151	183	2,700	4/	226
906	52,774	28,996	-----	2,598	-------	124	161	2,561	4/	210
907	47,945	28,374	-----	2,451	-------	90	114	2,305	5/13,714	285
908	22,680	35,039	-----	2,870	-------	105	128	2,520	5/11,221	267
909	37,589	32,218	-----	2,715	6/ 805	123	149	2,431	7/	257
910	38,426	35,192	-----	2,351	6/ 571	138	167	2,502	--------	319
911	48,381	45,558	-----	1,923	-------	147	160	2,648	--------	165
912	38,388	43,356	-----	1,674	-------	---	224	2,309	--------	---
913	52,658	50,225	-----	2,001	6/ 933	---	---	8/ 2,410	--------	---
914	56,608	31,907	9/	1,263	6/ 613	---	---	2,537	--------	---
915	60,785	14,869	9/	510	6/ 192	---	---	2,497	--------	---
916	93,916	12,565	9/	1,289	6/ 86	---	---	2,293	--------	---
917	98,770	-------	9/	800	-------	---	---	2,335	--------	---
918	80,553	-------	9/	523	6/ 262	---	---	2,210	--------	---
919	60,007	10,112	9/	519	6/1,694	10/	11/103	2,062	4,760	---
920	109,152	15,819	9/	261	6/1,608	10/	11/ 89	1,718	12,682	---
921	45,359	17,536	9/	404	6/2,629	10/	11/ 75	2,490	9,673	---
922	77,310	33,280	9/	555	1,731	10/	11/104	2,448	12/9,013	---
923	123,967	34,664	9/	253	1,237	---	101	2,478	24,000	---
924	105,333	32,418	9/	6/519	2,137	---	207	2,695	24,000	---
925	103,147	6/39,059	9/	6/622	2,331	---	72	3,636	16,000	---
926	105,206	34,669	9/	532	6/1,064	---	44	3,655	18,360	---
927	98,956	20,300	9/	549	551	---	34	3,592	17,881	13/
928	118,841	18,934	9/	267	563	---	29	3,744	14,943	1
929	154,104	9/	9/	9/	935	---	48	14/3,600	13,528	13/
930	9/	9/	9/	9/	9/	9/	9/	14/3,700	6,000	9/

/Data mainly from the Mineral Resources (Annual) of the United States Geological urvey and Bureau of Mines, the Mineral Industry of the British Empire and Foreign ountries, (Annual) and the Annual Report of the Mineral Resources of the U.S.S.R., 926 and 27. 2/Reported boracite, but may be pandermite, a calcium borate. 3/Produced in Tibet, but exported from India. 4/Annual output of about 9,000 tons. 5/ ears ending March, 1908 and March, 1909. 6/Exports. 7/Annual output of 10,000 to 11,000 tons. 8/The crude acid is manufactured into refined acid and borax, for which orms of production statistics are quoted. 9/Information not available. 10/Prussian nly. 11/See German Empire. 12/Imports into various countries from Turkey. 13/Less han one ton. 14/Estimated.

During the eighties, however, a new source of borax and boric acid was discovered in the mineral colemanite (a calcium borate), which was contained in vein deposits in the Tertiary formations. This revolutionized the borax industry, once more entirely shifting the basis of production. The raw material as mined was a compact ore mineral which was submitted to a process of manufacture in plants erected for the purpose. Reports of this production were then stated in terms of crude colemanite or calcium borate as mined but as production of refined borax from both the old marsh deposits and the new vein source continued for a time, it was difficult to combine the statistics in a single total.

The following Table 3 shows the output of crude and refined borate minerals, together with their value for the years 1900-1930, inclusive.

During the latter part of 1926, announcement was made of the discovery of extensive deposits of rasorite, a new borax mineral which had not been previously known. Again the borax industry was shifted, and production increased considerably during the next three years. It is estimated that rasorite accounts for approximately two-thirds of the total output of borate minerals, Searles Lake brines nearly one-third, only about 300 tons being supplied from all other domestic sources.

The reserves of borax in the Mojave Desert and the Great Basin regions are so large that the amount mined could be increased considerably if the demand could be stimulated further. Domestic deposits are sufficient to furnish the entire world with borax for many years to come.

Table 2.- Production of borate materials in the United States, 1864-1902, short tons[1]

Year	Crude	Refined	Value	Year	Crude	Refined	Value
1864	- - -	12	$9,478	1884	- - -	3,500	$490,000
1865	- - -	125	94,099	1885	- - -	4,000	480,000
1866	- - -	201	132,538	1886	- - -	4,889	488,915
1867	- - -	220	156,137	1887	- - -	5,500	550,000
1868	- - -	32	22,384	1888	- - -	3,795	455,340
1869	- - -	0	0	1889	- - -	4,000	500,000
1870	- - -	0	0	1890	- - -	4,750	617,500
1871	- - -	0	0	1891	- - -	6,690	869,700
1872	- - -	140	89,000	1892	- - -	6,750	900,000
1873	- - -	1,000	496,000	1893	- - -	4,350	652,425
1874	- - -	2,000	567,000	1894	- - -	7,340	974,445
1875	- - -	2,717	672,000	1895	- - -	5,959	595,900
1876	- - -	2,590	563,000	1896	- - -	6,754	675,400
1877	- - -	1,864	364,000	1897	- - -	8,000	1,080,000
1878	- - -	1,401	249,000	1898	- - -	8,000	1,120,000
1879	- - -	792	143,000	1899	- - -	20,357	1,139,882
1880	- - -	1,846	277,233	1900	24,235	1,602	1,018,251
1881	- - -	2,023	304,461	1901	17,887	5,344	1,012,118
1882	- - -	2,118	338,903	1902	2,600	2/17,404	2,538,614
1883	- - -	3,250	585,000				

1/ Mineral Resources of the United States, Part II, (Annual.
2/ Last year for which refined figures were published.
Note.-Prior to production from Nevada, prices ranged from 28 to 35 cents a pound for the refined borax extracted from the California lake waters. After 1872 the price dropped during the next two years to $6\frac{1}{2}$ cents a pound; it then advanced slowly to 11 to 13 cents, but again fell off. In 1885 borax sold in San Francisco for 6 to 8 cents a pound; a further decline followed. From 1882 to 1902 inclusive, the refined product was used as a basis for estimating the value

Table 3.- Production of crude borate minerals in the United States[1]

Year	Quantity, short tons	Value	Year	Quantity, short tons	Value
1900	24,235	2/	1915	67,003	$1,677,099
1901	17,887	2/	1916	103,525	2,409,459
1902	2,600	2/	1917	108,875	3,609,632
1903	34,430	$ 661,400	1918	88,794	2,263,230
1904	45,647	698,810	1919	66,146	1,380,000
1905	46,334	1,019,154	1920	120,320	2,173,000
1906	58,173	1,182,410	1921	50,000	1,600,000
1907	52,850	1,121,520	1922	85,220	2,705,140
1908	25,000	975,000	1923	136,650	3,994,790
1909	41,434	1,534,365	1924	116,110	3,183,910
1910	42,357	1,201,842	1925	113,700	3,085,660
1911	53,330	1,569,151	1926	115,970	3,128,110
1912	42,315	1,127,813	1927	109,080	3,473,399
1913	58,051	1,491,530	1928	131,000	3,999,773
1914	62,400	1,464,400	1929	169,870	4,515,375
			1930	177,360	5,351,999

1/ Mineral Resources of the United States, Part II (Annual), and Preliminary Summary of the Mineral Products of the United States (Annual).

2/ Not available.

Figure I shows the trend of production of borax in the United States from the discovery of the first crystals in the lake mud from Lake County, Calif., up until the discovery of rasorite in Kramer County of the same State. There is also shown graphically the periods during which each source of borax was actively worked and the effect on the trend of production by the various changes in the basis of production.

Refined Borax

The output of refined borax in the United States for the years 1900 to 1930 is shown in Table 4. Since 1921, however, the statistics are for every other year, but it will be seen that the production of refined borax has kept pace with the output of borate materials.

Table 4.- Production of refined borax in the United States[1]

Year	Short tons	Value	Year	Short tons	Value
1900	1,602	2/	1915	26,794	$2,293,631
1901	5,344	2/	1916	27,969	3,353,432
1902	17,404	2/	1917	28,309	3,805,711
1903	- - -	- - -	1918	26,673	3,909,565
1904	- - -	- - -	1919	28,518	4,351,891
1905	- - -	- - -	1920	35,281	5,674,012
1906	- - -	- - -	1921	18,499	2,745,192
1907	- - -	- - -	1922	3/	3/
1908	- - -	- - -	1923	53,092	5,102,148
1909	- - -	- - -	1924	3/	3/
1910	- - -	- - -	1925	49,967	4,083,209
1911	- - -	- - -	1926	3/	3/
1912	- - -	- - -	1927	64,864	5,079,278
1913	- - -	- - -	1928	3/	3/
1914	26,501	$2,071,774	1929	92,250	3,279,641
			1930	3/	3/

1/ Mineral Resources of the United States, Part II (Annual).
2/ Not reported separately.
3/ No published statistics.

Organization of the Domestic Industry

Practically the entire production of borate minerals in the United States at present is under the control of four major companies, two of which, the Pacific Coast Borax Co., and the American Potash and Chemical Co., are reported as being controlled by British capital. The third company is the West End Chemical Co. and its associates, among which is the West End Mining Co., Las Vegas, N. Mex. Its borax is marketed mostly through the Borax Union, a concern associated with the Stauffer Chemical Co. of San Francisco. The West End Chemical Co. operates a plant at West End, Searles Lake, the daily output being about 15 to 20 tons (1929).[16]

The Burnham Chemical Co. is also operating at Searles Lake, though not extensively. There was no production, however, by this company in 1930.

The fourth producer is the Western Borax Co., operating adjacent to the Hinkley works of the Pacific Coast Borax Co. This company, also closely associated with the Stauffer Chemical Co., began production of rasorite in the Kramer district in the latter part of 1928. One other smaller company, the Sukow Chemical Co., closed down its plant in 1925 and has had no output since.

A new company, the Pacific Alkali Co., started operating in 1930. Their plant is located at Bartlett, Inyo County, while their main office is at Los Angeles.

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16 - Manning, Paul D. V., Work cited, p. 680.

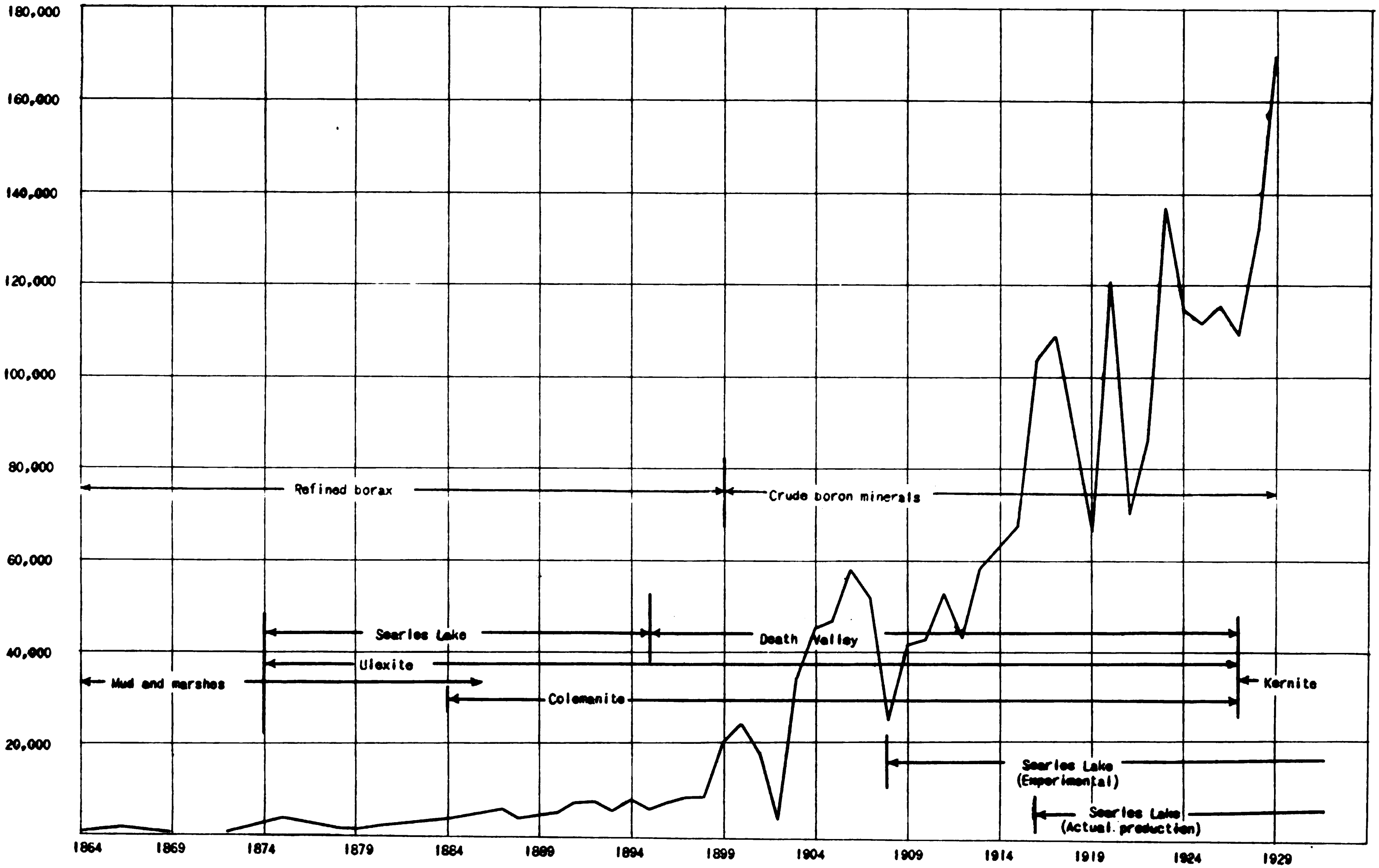

Figure 1.– Production of boron minerals in the United States, showing sources of supply (short tons)

The American Potash and Chemical Co. (the old American Trona Co.), producer of "Three Elephant Borax," brought its new plant to full production of 125 tons of borax per day in 1927. This is the largest borax plant in the world and at present is being greatly increased in size and capacity. At this plant borax is produced as a by-product in the manufacture of potassium chloride. This company also manufactures about 20 tons of boric acid per day.

For some years the production of borax in the United States was largely controlled by the Pacific Coast Borax Co. (manufacturers of "Twenty Mule Team Borax"). This company, a subsidiary of Borax Consolidated (Ltd.), a British company, operated in Death Valley, Calif.

When the American Potash and Chemical Co. started up its new plant in 1927, the Pacific Coast Borax Co. closed down its plant in Death Valley and centered its operations on the extensive rasorite deposits at Kramer. The refining of borax by this company is carried on at a large plant at Wilmington, Calif. The total capacity of this plant is 5,000 tons per month.[17]

Imports

The imports of boron minerals and refined borax are quite small. It is of interest to note, however, that the imports of crude borate minerals have tended markedly to increase during the last few years despite the rapid growth in production and exports; in 1929 they amounted to over 5,000 short tons, valued at $157,793. There were no imports recorded in 1930. These imports are destined primarily for consumption along the Atlantic seaboard and are refined at numerous chemical plants in this region.

Imports for consumption in the United States of borate minerals and refined borax are shown in Tables 5 and 6. Of the imports of borate minerals, Turkey and Chile furnish the larger part, while England furnished varying amounts of refined borax to this country.

Table 5.- Imports for consumption of borate minerals into the United States[1]

Year	Pounds	Value	Year	Pounds	Value
1900	273,706	$9,937	1915	- - - -	- - - -
1901	545,045	20,643	1916	83	$3
1902	684,537	20,795	1917	- - - -	- - - -
1903	68,978	5,727	1918	10,000	50
1904	153,952	10,569	1919	550	25
1905	166,960	8,802	1920	5,050	100
1906	791,425	27,343	1921	7,840,000	167,500
1907	2,268,065	77,258	1922	900	14
1908	641,632	22,058	1923	17,001,000	328,960
1909	7,124	1,023	1924	6,480,167	91,961
1910	6,860	1,170	1925	4,480,000	74,098
1911	9,582	732	1926	9,192,164	130,012
1912	9,280	636	1927	15,680,000	230,251
1913	4,215	477	1928	10,080,000	145,353
1914	220	29	1929	10,180,000	157,793

1/Foreign Commerce and Navigation of the United States (Annual) Department of Commerce, and the Mineral Resources of the United States, Part II (Annual)

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[17] - Manning, Paul D.V., The Mineral Industry in 1928: New York, 1929, p. 66.

Table 6.- Imports for consumption of refined borax into the United States[1]

Year	Pounds	Value	Year	Pounds	Value
1900	2/58,294	$4,306	1915	2,748	$596
1901	103,700	9,411	1916	703	135
1902	186,807	12,002	1917	110	7
1903	146,654	13,280	1918	2	1
1904	89,447	6,630	1919	378	155
1905	20,395	1,626	1920	30,563	2,451
1906	57,711	2,436	1921	226,240	12,477
1907	2,959	175	1922	778	257
1908	40	4	1923	943	151
1909	20,284	1,956	1924	168,960	6,944
1910	563	66	1925	1,659	292
1911	28,815	5,230	1926	8,966	881
1912	16,091	1,861	1927	13,198	1,115
1913	7,900	1,125	1928	210,534	4,906
1914	3,862	546	1929	7,504	1,323
			1930	16,681	1,993

1/ Foreign Commerce and Navigation of the United States (Annual) Department of Commerce.

2/ 1900-1917 includes "borates, calcium, and sodium (crude)."

Tariff History

Borax and borates first received specific mention in the tariff act of 1897. The duties provided for under that act were substantially reduced in the Payne-Aldrich Act of 1909, and, in the Underwood Act of 1913 the duty on refined borax was cut to 1/8 cent a pound and crude borax and other boron minerals were transferred to the free list. No changes in the tariff status were made in the acts of 1922 and 1930.

Exports

Prior to 1914, exports of borax from the United States were small, but during the World War a substantial business developed with Europe. Prior to 1920, the statistics were not kept separately, but since that date the exports have increased enormously, reaching 165,862,630 pounds (82,931 short tons) valued at $3,057,794 in 1930, as compared with only 4,061,633 pounds (2,031 short tons) having a value of $269,771 in 1921. This represents approximately one-half of the domestic output and reflects the fact that the major part of the world's requirements for this mineral is supplied from the borax deposits in California and Nevada. England, Germany, Japan, and Canada are the principal markets for American borax and borate materials.

The exports consist principally of refined borax, although crude borate materials are also shipped, mostly to Europe for the manufacture of refined borax and boric acid.

Table 7.- Rates of duty on borax[1]

Act of	Par.	Tariff Classification	Rates of duty specific and ad valorem
1897	11	Borax;	5 cents per lb.
		borates of lime or soda or other borate material not otherwise provided for containing more than 36 per cent of anhydrous boracic acid;	4 cents per lb.
		borates of soda, or other borate material not otherwise provided for, containing not more than 36 per cent of anhydrous boracic acid,	3 cents per lb.
1909	11	Borax;	2 cents per lb.
		borates of lime, soda or other borate material not otherwise provided for in this section.	Do.
1913	67	Soda: Borate of or borax refined.	1/8 cent per lb.
	429	Borax, crude and unmanufactured and borate of lime, soda, and other borate material, crude and unmanufactured, not otherwise provided for in this section.	Free.
1922	83	Sodium: *** borate or borax, refined; *****	1/8 cent per lb.
	1532	Borax, crude or unmanufactured, and borate of lime, *****	Free.
1930	81	Sodium: *** borate or borax, refined.	1/8 cent per lb.
	1633	Borax, crude or unmanufactured, and borate of lime, borate of soda, and other borate material, crude and unmanufactured, not specially provided for.	Free.

1/ Tariff Information Surveys, U. S. Tariff Commission A-1, 1921, p. 18.

Table 8.- Exports of borax from the United States[1]

Year	Pounds	Value
1920	14,325,037	$1,206,936
1921	4,061,633	269,771
1922	17,650,571	875,101
1923	40,551,064	1,607,419
1924	33,741,676	1,601,375
1925	33,888,235	1,528,035
1926	28,610,037	1,256,798
1927	73,907,981	2,422,144
1928	135,702,837	3,454,171
1929	159,767,825	2,934,660
1930	165,862,630	3,057,794

1/ Foreign Commerce and Navigation of the United States (Annual), Department of Commerce.

2/ Not recorded separately prior to 1920.

Consumption

Table 9 shows the apparent consumption of borate minerals and crude borax. This does not take into consideration stocks on hand, as this information is not available.

Production has been increasing rapidly, but exports have increased even more rapidly; and since imports have remained stationary (approximately 5,000 tons annually), the indicated domestic consumption has declined. This decreased consumption may be caused by a decided slump in the building constr tion industry, which uses approximately one-third of the total consumption of borax for enameling cast-iron and steel plumbing fixtures and kitchen equipm The monthly shipments of enameled ware (baths, lavatories, sinks, and miscellaneous) for example, have decreased from 429,338 pieces in 1925 to 202,846 pieces in 1930.[18]

The use of borax in the glass industry (container glass) has increas considerably in recent years, due to the advances made in the chemistry and technology of borosilicate glasses and container glass. Borax has been used heretofore only in the manufacture of higher-priced glass, notably that which is heat resisting. The results of several years research on the part of one o the large borax producers have been made available to the glass industry as a whole, and the use of borax has increased favorably. According to the "Survey of Current Business"[19] the shipments of container glass increased from 1,805,0 gross monthly in 1925 to 2,273,000 gross monthly in 1930.

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18 - U. S. Bureau of Foreign and Domestic Commerce, Survey of Current Business: No. 108, Aug., 1930, p. 43, and No. 114, Feb., 1931, pp. 34-35.

19 - Bureau of Foreign and Domestic Commerce, Work cited, p. 77 and p. 35.

Table 9.- Consumption of borate minerals and crude borax in the United States, 1919-1929, short tons[1]

Year	Production borate minerals	Imports borate minerals	Imports crude borax	Exports borax	Apparent consumption
1919	66,146	1	- - -	- - -	66,147
1920	120,320	2	- - -	7,162	113,160
1921	50,000	3,920	- - -	2,031	51,889
1922	85,220	1	3,227	8,325	80,123
1923	136,650	8,501	958	20,276	125,833
1924	116,110	3,240	1,120	16,871	103,599
1925	113,700	2,240	3,360	16,944	102,356
1926	115,970	4,596	- - -	14,305	106,261
1927	109,080	7,840	- - -	36,954	79,966
1928	131,000	5,040	- - -	67,851	68,189
1929	169,870	5,090	- - -	79,884	95,076
1930	177,360	- - -	- - -	82,931	94,429

1/ Mineral Resources of the United States (Annual) Part II.

Foreign Countries

Chile and Bolivia

Borates in the form of ulexite or boronatrocalcite occurs throughout the desert regions of Atacama along the border between Chile and Bolivia directly inland from Antofagasta.[20] At Ascotan (Antofagasta) on the border between these two countries and at Maricunga, to the north of Copiapo, halfway between Coquimbo and Antofagasta are found the largest operations.

The deposits are extensive and are found in desiccated lakes known as salares. These salares are extensively scattered over the arid portions of northern Chile and southern Peru, and, though probably all contain some borate, only a small proportion contain enough to render them workable. The richest are those of the valleys of the High Andes in the vicinity of the recent volcanoes, many of which still have active fumeroles.

The Salar de Ascotan, near the village of Ascotan, is much the largest and is connected with the coast by a railroad running from La Paz, Bolivia, to Antofagasta, Chile. It is the center of practically all the borate mining of Chile. This region is about 24 miles in length from north to south, and about 6 miles wide at the broadest part. In the intense sunshine the salar presents a dazzling appearance, for, excepting a small pool of water here and there, the entire area is covered with glistening white crystals of various salts.

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[20] - Imperial Mineral Resources Bureau, Borates: The Mineral Industry of the British Empire and Foreing Countries, London, 1920, pp. 19-20.

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On the eastern side there are several volcanoes with well-preserved craters, some of which have active fumaroles. The salar is situated at an altitude of 12,220 feet above sea level, and the adjoining volcanic mountains range from 18,000 to 19,600 feet.

In some places the ulexite is found practically free from impurities but elsewhere it is associated with sodium chloride, sodium sulphate, and calcium sulphate. The thickness of the rich strata is usually not more than 1 foot, but considerably thicker beds have been reported.

Peru

Borates are found in the southern part of Peru along the boundary between the departments of Arequipa and Moquega at Laguna de Salinas, about 12 miles east of Arequipa City.[21] The lake is some 8 miles in circumference and lies at an altitude of 18,000 to 20,000 feet. It is dry practically througho the whole of the year, and the borates form an irregular layer, the upper crus consisting of chloride and sulphate of soda, followed successively by fine sa coarse sand, sand with borate layers, thin layers of sand, and a 40-centimeter to 1-meter layer of borates.

The mineral is ulexite, containing 30 per cent of boric acid in the crude state and 52 per cent after being calcined.

Argentina

Deposits of borates are found in Las Andes and the immediately adjacent portions of Jujuy, Salta, and Catamarca in northwestern Argentina in large lakes and salares.[22] The borate in the form of ulexite usually occurs mixed with calcium and sodium sulphate, sodium and magnesium chloride, oxide of iron and more or less sand and clay. It is found partly as layers of massive material and partly as pebbles and concretions, the latter form being the richer in boric acid. The deposits are much the same as those found in Chile and Peru and as a matter of fact are all in the general area.

The Tres Morros, which is the most actively worked deposit in Argentina, consists of a layer of concretions 80 to 100 centimeters (approximately 2 to 3 feet) thick, containing about 37 per cent of boric anhydride.

The deposits that are being worked at present are under the control of the Belgian International Co.

Other Foreign Countries

Commercial deposits of borates are found in several other countries, namely, Germany, Turkey, India, and Tibet.

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[21] - Imperial Mineral Resources Bureau, Work cited, p. 20.

[22] - Imperial Mineral Resources Bureau, Work cited, pp. 18-19.

In Germany, borax occurs as boracite, a borate of magnesium, in the form of crystals, concretions, and granular masses associated with potash minerals in salt deposits of Permian age at Stassfurt. Rock salt, which is found almost throughout the section, contains disseminated borates, but the carnallite zone, measuring 90 to 120 feet in thickness, yields most of the crude boracite.

Borates have been known in Asia Minor since ancient times in the vilayet of Brusa at Sultan-Chair near Panderma, Turkey, from which the local name "pandermite" is derived.[23] Pandermite is the firm compact, porcelain-like masses of colemanite. It contains a higher percentage (56 per cent) of boric acid than any other borate mineral except boracite and rasorite.

Sultan-Chair, which is the mining center, lies between the Manissa-Sona-Panderma branch of the Smyrna-Cassaba railway, 37 miles southwest of Panderma and 51 miles southwest of Brusa. The basin of Sultan-Chair lies among hills of schist and granite of early geological age. Sedimentary deposits of later age, chiefly gypsum, have accumulated to a great depth. Volcanic upheaval during the period of the gypsum formation probably accounts for the trachyte outflow which is found to the north of the basin, as well as for the fumeroles that yielded the boric acid.

The borax deposits occurring in Tibet were probably the first borates ever utilized. The material exported from Tibet is obtained from salt lakes which have possibly received their borax from a volcanic source. The borax obtained from the Puga Valley of Ladakh, Kashmir, is deposited from hot springs associated with sulphur deposits, which are regarded as evidence of waning volcanic action.

Competitive Conditions

The United States produces more than half of the world's consumption of borate minerals. Nevertheless, as far as prices are concerned, the United States has enjoyed very few periods of prolonged stability. The periodical shifting of the basis of production, from mud to marsh deposits, and from ulexite to colemanite, to saline waters and finally to rasorite, has seriously affected the price of crude and refined borax.

In recent years competition of by-product borax with rasorite, as well as more or less severe competition between the larger producers in California, has resulted in great uncertainty in the price of borax, there being practically no standard price at present.

Unusual as it may seem, the price situation has had little or no apparent affect upon production and sales of borax in this country, while the exports of crude borax have increased greatly in recent years.

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[23] - Imperial Mineral Resources Bureau, Work cited, p. 18.

Domestic exports of borax are chiefly by a British concern which formerly had a world monopoly of the production of both crude and refined borax. Several years ago, however, another large domestic manufacturer began production. This company produces only refined borax and not crude borate materials. Although both are financed largely by British capital there is keen competition between these two companies.[24]

American crude borax is exported principally to England, Germany, France, Canada, and Japan, though these countries also purchase some supplies from Chile and Turkey. To protect their refining industry, these countries levy a duty upon refined borax but permit crude borate materials to enter duty-free.

Market and Prices

The chief market for borax is in the manufacture of enamels or porcelain-like coatings for metal utensils, such as bathtubs, kitchen sinks, cooking utensils, and the like. An important and growing demand for borax is for the manufacture of container glass, the quantity used for this purpose having practically doubled during the past five years. The present price of borax which is lower now than at any time in the history of the industry, has enabled this product to compete in the glass industry with soda ash and has resulted in a greatly increased demand for borax.

With the discovery of borax in the United States in 1864, the refined product was quoted at from 28 to 35 cents a pound. The production of ulexite which started in Nevada in 1874, caused the price to fall considerably, reaching 6 1/2 cents in that year. It then advanced to 11 to 13 cents a pound, but again fell off. In 1885, with the discovery of colemanite, borax was priced at 6 to 8 cents a pound. The price fluctuated around these figures until about 1900, when it started a slow decline. By 1914, the price of borax crystals was quoted at 3 3/4 to 4 cents a pound. With the war came higher prices but by 1922, the price had again fallen, reaching 5 cents a pound during that year. Since then there has been a steady decrease; in 1930, borax crystals were quoted at 2 3/4 cents a pound.

The following Table 10 shows the prices of borax crystals and borax, granulated or powdered, for the years 1922 to 1930, inclusive.

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[24] - U. S. Tariff Commission, Summary of Tariff Information; 1929, Schedule 1, p. 379.

Table 10.- Prices of Borax Crystals and Granulated or Powdered Borax[1]

Year	Borax crystals	Borax, granulated or powdered
	Per pound, in bags	Per pound, in bags
1922	$0.05325	$0.05833
1923	.05250	.05250
1924	.05000	.05000
1925	.04166	.04750
1926	.04083	.04625
1927	.04208	.03958
1928	.03375	.03125
1929	.02750	.02500
1930	.02750 2/	.02500 2/

1/ Engineering and Mining Journal (Weekly), New York.

2/ Six months only, $56 a ton for crystals and $50 a ton for granulated or powdered.

BORIC ACID

Description

Boric acid (boracic acid or orthoboric acid, H_3BO_3) is a feeble acid and a mile antiseptic. It is a white crystalline substance that is readily soluble in hot water and forms salts with many metals. It crystallizes from hot aqueous solutions in lustrous, colorless, flexible, six-sided plates which feel greasy to the touch. It is soluble in alcohol and melts at 184° C. The specific gravity is 1.4347.

Uses

Boric acid has numerous applications in industry. One of its principal uses is for the manufacture of borates and other chemicals. A growing use, however, and one which may account for the consumption of the larger part of the domestic sales of boric acid is for the manufacture of special glasses. Boric acid like borax, is used in connection with other acid oxides to produce glasses which are very resistant to chemical action, especially if the proportion of boric anhydride is not greater than 10 per cent. It is this sort of glass that is being used in the manufacture of high-grade beakers, flasks, and other laboratory glassware.

Boric acid is recognized as an antiseptic and is used in eye lotions and various external washes, as a detergent wash for mucous membranes and dressings for wounds. It is also used in soaps and in cosmetics such as borated talcum powder.

Boric acid is used largely in Europe in the preservation of foods, especially smoked and dried meats, sausage, fish, and dairy products. In the United States this use has been almost entirely prevented by the provisions of the Pure Food and Drug Act, except on food intended for export and in salt fish, especially cod fish. Its use in salt fish is permitted because these foods are usually soaked in water before consumption, which removes most of the boric acid.[25]

Boric acid is also used[26] in the manufacture of water glass and in producing nitric acid from saltpeter with simultaneous production of borax. It is used in high-grade cements capable of taking high polishes; for impregnating wicks of stearin candles; in laundry starch glazes, and in the preparation of hides prior to tanning, and in leather dressing compounds. In metallurgy, boric acid is used as a welding flux, for brazing copper, and for enameled coatings on iron and steel. It is used in fireproofing compositions and for linings of safes, for pigments (Guinet's green and borated ultramarine) for enamel paints, for the manufacture of imitation hardwood from softwood, for paper glazes, as a mordant in the textile industry, and as a solvent bleach and finally as a preservative in wine making.

Sources of Supply

Boric acid is found free in nature and as the mineral sassolite in many volcanic districts. It is produced, however, in large quantities from other borate minerals.

In central Italy boric acid is obtained in considerable quantities from gaseous emanations which come to the surface through innumerable fissures or dislocations in the Eocene and Cretaceous rocks. These fumarole deposits occur chiefly in the parishes of Pomerance, Castel Nuovo di Val di Cecina, Massa Marittima, and Montieri, in the Province of Pisa, Department of Tuscany. Boric acid also occurs in the extinct crater of a volcano on one of Lipari Islands, and in the crater of Stromboli, an active volcano on another island of the same group, near Sicily. Volcanic emanations containing boric acid occur in the United States in Nevada and California and in Nova Scotia, Canada. These deposits in the United States and Canada, however, are not utilized for the production of boric acid.

Sassolite, first found near Sasso, Tuscany, is never produced in the pure state, but is always associated with impurities, both soluble and insoluble. It differs considerably in quality, ranging from 75 to 90 per cent of boric acid.[27]

Preparation

Boric acid was formerly obtained by sublimation from a mixture of 15 parts of borax, 5 of sulphuric acid, and 2 of water, heated in a retort; the

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25 - U. S. Tariff Commission, Tariff Information Surveys, 1921, p. 12.

26 - Chemical Catalog Co., The Condensed Chemical Dictionary: New York, 2nd ed., 1930, p. 81.

27 - Thorpe, Edward, Dictionary of Applied Chemistry: London, vol. 1, 1921, p. 640.

powdered residue was frequently moistened with water and again ignited. The yield was small. It is now made by treating a solution of 1 part of borax in 4 parts of boiling water with one-third the quantity of sulphuric acid. On cooling the solution boric acid crystallizes out and a further quantity can be obtained by evaporating and cooling the solution. Hydrochloric acid may be used instead of sulphuric acid.

Boric acid may be obtained from pandermite and other calcium borates by suspending the powdered mineral in water and adding sulphuric acid. A current of steam is blown into the liquid, so that the boric acid dissolves and the calcium sulphate is converted into a compact form which is readily separated. The temperature is not allowed to rise over 80° or some boric acid will be lost in the vapor. The filtered liquid is cooled and allowed to crystallize. The crystals are purified, if necessary, by recrystallization. Hydrochloric acid may be used instead of sulphuric acid as in the case of preparing boric acid from borax.[28]

Production

The production of boric acid in the United States has approximately trebled since 1914. Prior to 1917, figures were collected annually by the U. S. Geological Survey. Subsequently only the biennial figures obtained by the Bureau of the Census are available. Tables 11 and 12 show the output of boric acid in the United States as published by these two agencies.

Table 11.- Domestic production of boric acid[1]

Year	Quantity, pounds	Value
1914	8,590,000	$ 588,981
1915	8,540,000	672,380
1916	11,624,000	1,227,005
1917	11,776,000	1,383,783

1/ Tariff Information Surveys, Tariff Act, 1913, A-1, 1921, p. 14.

Table 12.- Domestic production of boric acid[1]

Year	Number of establishments	Quantity, pounds	Value
1919	---	13,454,100	$1,754,632
1921	5	12,692,370	1,780,589
1923	3	17,277,801	1,736,081
1925	4	15,604,654	1,202,382
1927	6	21,009,603	1,582,565
1929	---	23,243,662	1,452,893

1/Bureau of the Census, Census of Manufacturers (Biannual).

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28 - Mellor, J. W., Inorganic and Theoretical Chemistry: Vol. 5, London, 1924, pp. 51-52.

Imports

Imports for consumption of boric acid into the United States for the years 1900 to 1930, inclusive, are shown in Table 13. While the imports have been more or less steady, there has been a tendency to decrease. In 1929, they amounted to only 7,472 pounds, valued at $431, the first time that they have ever fallen below 100,000 pounds. The larger part of this acid comes from Italy.

Table 13.- Imports for consumption of boric acid into the United States[1]

Year	Pounds	Value	Year	Pounds	Value
1900	473,251	$17,436	1916	354,710	$19,905
1901	725,005	26,629	1917	341,622	21,199
1902	822,907	30,439	1918	259,096	26,436
1903	693,619	28,011	1919	276,795	20,716
1904	708,815	27,658	1920	189,667	9,733
1905	676,105	22,372	1921	605,330	44,044
1906	986,021	33,200	1922	2/799,109	62,911
1907	534,524	23,547	1922	3/ 44,092	2,204
1908	385,064	14,702	1923	301,746	23,306
1909	265,985	8,708	1924	325,042	18,352
1910	336,466	11,164	1925	292,325	17,837
1911	458,900	17,666	1926	179,740	12,028
1912	232,545	8,752	1927	134,907	8,222
1913	423,215	16,932	1928	405,545	19,895
1914	425,241	18,837	1929	7,472	431
1915	442,073	20,888	1930	155,421	6,788

1/ Foreign Commerce and Navigation of the United States (Annual), Department of Commerce.

2/ Jan. 1 - Sept. 21.

3/ Sept. 22 - Dec. 31.

Tariff History

Table 14 gives the rates of duty applicable to boric acid for the various tariff acts since this commodity first received specific mention in the tariff act of 1897.

Table 14.- Rates of duty on boric acid

Act of	Par.	Tariff classification	Rates of duty specific and ad valorem
1897	1	Acids: Boracic	5 cents per lb.
1909	1	Acids: Boracic	3 cents per lb.
1913	1	Acids: Boracic	3/4 cent per lb.
1922	1	Acids: Boric	1 1/2 cents per lb.
1930	1	Acids: Boric	1 cent per lb.

1/ Tariff Information Surveys, U. S. Tariff Commission A-1, 1921, p. 18, and Tariff Information Summary, 1929, Schedule 1, p. 5.

Exports

With the increase in the production of borate minerals in the United States, the exports of boric acid have likewise increased, reaching 2,602 tons valued at $180,381 in 1929, compared with 781 tons, valued at $189,581 in 1922. It will be noted that while the quantity exported has increased about 235 per cent, the total value has actually declined. The average value per pound dropped from 12 cents in 1922 to 3.4 cents in 1929.

Table 15.- Exports of boric acid from the United States[1]

Year	Quantity, pounds	Value	Value per pound
1922	2/1,560,996	$189,581	$0.121
1923	891,670	104,912	.117
1924	727,082	79,081	.108
1925	766,234	78,158	.102
1926	1,414,655	125,777	.088
1927	----	----	----
1928	3,382,183	189,627	.056
1929	5,203,881	180,381	.034
1930	2,804,269	124,935	.044

1/ Tariff Information Summary, 1929, Schedule 1, p. 5, and Foreign Commerce and Navigation of the United States (Annual), U. S. Department of Commerce, vol. 1, 1929, p. 184.

2/ Exports of boric acid are not separately shown prior to 1922.

Market and Prices

The chief market for boric acid is in the manufacture of other chemicals, while about 25 per cent of the total output is dispensed through wholesale and retail druggists and dealers that supply household requirements. The remainder is distributed among meat and fish packers, manufacturers of glass, soap and cosmetics, and potters.

During the past four or five years the domestic price of boric acid has been gradually declining. The average price in 1925 for boric acid in crystals was $0.085 per pound. This dropped to $0.0825 in 1926, to 0.08, 0.07, and 0.06 per pound for the next three years, and in 1930 the price was quoted at $0.0558 a pound.

Italy

Production

The boric-acid industry in Italy is controlled by the Societa Boracifera, with headquarters at Larderello.[29] This company established in

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29 - Treves, M., Growth of Italian Chemical Industry Continues: Chemical Markets, vol. 28, No. 2, Feb., 1931, p. 143.

1912, following the merger of the various concerns operating the boric acid industry, now owns eight plants in the region surrounding the Cornia and Cecina Rivers, in the Province of Piza, Department of Tuscany.

The activity of this company is twofold - chemical and electrical. Both branches of its business are based on the utilization of natural steam which arises out of the so-called "soffioni," or steam spouts. During recent years, however, much larger quantities of steam are obtained and better conditions of exploitation are possible, by drilling. The drill holes are of variable depth, some of them reaching 1,500 feet.

Table 16, following, shows the output of crude boric acid from the natural fissures and drill holes for the years 1900 to 1930, inclusive. As regards natural boric acid, Italy has a virtual monopoly, but other countries are able to compete with Italy in the world markets with boric acid manufacture from borax.

Table 16.- Production of crude boric acid in Italy[1]

Year	Short tons	Year	Short tons
1900	2,746	1916	2,527
1901	2,820	1917	2,574
1902	3,046	1918	2,436
1903	2,847	1919	2,273
1904	2,892	1920	1,894
1905	2,976	1921	2,745
1906	2,823	1922	2,698
1907	2,541	1923	2,731
1908	2,778	1924	2,971
1909	2,680	1925	4,008
1910	2,758	1926	4,029
1911	2,919	1927	3,959
1912	2,545	1928	4,127
1913	2,656	1929	2/ 4,080
1914	2,796	1930	2/ 3,970
1915	2,752		

1/ Mineral Resources of the United States Bureau of Mines (Annual) Part II, and Mineral Industry of the British Empire and Foreign Countries (Annual).

2/ Estimated.

Preparation

Up to the end of the eighteenth century, boric acid was obtained industrially almost exclusively from borax (tincal). In 1775, Hoeffer and Mascagni discovered boric acid in the waters of the Tuscany (Italy) lagoons of Monte Rotondo and Castelnuovo, and shortly afterwards it was found in the solid state at Sasso, hence the name "sassoline," afterwards changed to sassolite.[30]

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30 - Mellor, J. W., Work cited, p. 49.

In the vicinity of the lagoons, jets of boiling water seem to burst explosively from the earth, emitting clouds of steam. At a distance the boric-acid fumaroles and lagoons appear like clouds of vapor rising from the mountains. They occur over an area of about 30 square miles.

To recover the boric acid, it is necessary merely to evaporate the condensed vapors from the fumaroles. In 1807, Gazzeri analyzed the waters and concluded that the boric acid contained in them was too small to promise successful extraction on a large scale. Undeterred by this, attempts were made at Monte Rotondo in 1815, to extract the acid on a commercial scale, but the cost of fuel (charcoal) required for the evaporation was prohibitive. About 1828, the idea was conceived of applying the heat from the soffioni to evaporate their own waters instead of allowing it to waste itself in the air.

The present process of extraction and preparation of boric acid in Italy, based upon this idea is comparatively simple, and relatively inexpensive.

The steam that issues from numerous blow holes or soffioni in the ground in the neighborhood of Larderello (Mont Cerboli district) contains up to one-tenth of a per cent of boric acid. The vents either natural or artificially drilled are lined with about 8-inch pipes or casings which extend into the earth from a few feet to over 300 feet. The temperature of the issuing steam varies from 98° to 140° C.

Circular basins, about 30 feet in diameter, are built about the soffioni so as to include two or three vents. A series of such basins are built at different levels on the side of a hill so as to form a kind of terrace of artificial lagoons. The uppermost one is filled with water from the mountain streams. The hot vapors bubble up through the water, give up their boric acid, and raise the temperature of the water. In about 24 hours, the impregnated water is run into the next lagoon where a second impregnation occurs. In another 24 hours the liquid passes on to the third lagoon, and so on until it has reached the last of the series. The water will then have gathered about 2 per cent of boric acid. If impregnation is allowed to proceed further, boric acid will be carried off with the escaping steam. The solution is then allowed to settle in a rectangular settling-tank where the fine mud containing more or less boric acid is deposited. The water from the settling-tank is allowed to run down a series of corrugated lead-lined evaporating troughs, generally 6 feet wide, 150 feet long, and 8 inches deep. These troughs are heated by vapors from the soffioni. The liquid enters at one end and runs over the corrugations, where it is rapidly evaporated. If the temperature rises much above 50°C. there is a loss of boric acid with the vapor. Any further evaporation, if needed, is conducted in leaden pans. When concentrated to the point of crystallization -- about 1.116-specific gravity at 15° C. -- the liquid is transferred to wooden crystallization vats and allowed to cool. The mother liquid is returned to the evaporating pans while the crystals of boric acid are removed by wooden scoops, drained in baskets and dried on a floor heated by native steam. The first crystals are quite impure; but after recrystallizing, a product containing up to 97 or 98 per cent may be obtained. The purity varies, however, down to a minimum of 82 per cent. The dried nearly pure crystals are shipped raw or are refined and used for the manufacture of borax.

Ammonia which is also contained in the vapor is recovered separatel as is carbon dioxide, which is found in large quantities in the steam.

Imports and Exports

Table 17 shows the foreign trade of Italy of borax for the years 1900 to 1930, while Tables 18 and 19 show the trade in crude and refined boric acid for the years 1910 to 1930.

In addition to boric acid, Italy in recent years has been exporting increasing quantities of borax, the amount in 1930 being estimated at 3,504,360 pounds, the largest on record as the previous high figures included boric acid.

Table 17.- Italian imports and exports of borax[1]

Year	Imports into Italy		Exports from Italy	
	Pounds	Value	Pounds	Value
1900	2/ 268,888	3/	2/ 4,659,256	3/
1901	2/ 511,328	3/	2/ 4,826,760	3/
1902	2/ 1,137,264	3/	2/ 4,070,788	3/
1903	2/ 1,110,816	3/	2/ 1,985,804	3/
1904	2/ 597,284	3/	2/ 2,472,888	3/
1905	2/ 246,848	3/	2/ 4,970,020	3/
1906	2/ 359,252	3/	2/ 6,120,508	3/
1907	2/ 676,628	3/	2/ 2,931,320	3/
1908	2/ 733,932	3/	2/ 2,215,020	3/
1909	2/ 850,744	3/	2/ 3,755,616	3/
1910	609,131	$ 21,864	211,201	$ 7,581
1911	1,384,268	48,474	139,772	4,894
1912	675,269	23,646	190,918	6,686
1913	304,896	12,011	66,358	2,614
1914	610,674	26,731	9,700	425
1915	1,583,123	94,243	329,147	19,594
1916	2,167,783	237,221	1,167,556	127,766
1917	1,393,307	152,470	9,259	1,013
1918	771,400	116,876	4,408	700
1919	1,243,200	142,397	221,760	25,597
1920	2,869,440	217,255	80,640	6,071
1921	492,800	3/	22,400	3/
1922	629,440	39,953	4,480	305
1923	1,122,240	3/	2,240	3/
1924	1,984,640	3/	11,200	3/
1925	2,085,440	3/	11,200	3/
1926	1,102,030	3/	11,200	3/
1927	611,520	3/	4,480	3/
1928	627,200	3/	1,612,800	3/
1929	132,160	3/	1,223,040	3/
1930	4/	3/	5/ 3,504,360	3/

1/ Data mainly from the Tariff Information Survey 1921, and the Mineral Industry of the British Empire and Foreign Countries (Annual).

2/ Includes boric acid.

3/ Value not reported.

4/ Information not available.

5/ Estimated.

Table 18.- Italian imports and exports of crude boric acid[1]

Year	Imports into Italy		Exports from Italy	
	Pounds	Value	Pounds	Value
1910	441	$ 15	1,968,487	$77,548
1911	---	---	1,989,652	73,157
1912	---	---	1,871,926	68,828
1913	---	---	1,700,849	77,428
1914	220	12	1,475,539	77,505
1915	220	14	809,970	49,636
1916	---	---	604,722	74,116
1917	---	---	238,538	29,236
1918	---	---	275,500	57,132
1919	---	---	611,520	27,330
1920	22,400	585	815,360	21,178
1921	---	---	766,080	2/
1922	---	---	1,433,600	78,959
1923	---	---	3/	3/
1924	---	---	3/	3/
1925	---	---	3/	3/
1926	---	---	3/	3/
1927	---	---	3/	3/
1928	---	---	3/	3/
1929	---	---	4/749,360	2/
1930	---	---	4/760,380	2/

1/ Data mainly from The Tariff Information Survey, 1921, and The Mineral Industry of the British Empire and Foreign Countries (Annual).

2/ Value not reported.

3/ Information not available.

4/ Estimated.

Table 19.- Italian imports and exports of refined boric acid[1]

Year	Imports into Italy		Exports from Italy	
	Pounds	Value	Pounds	Value
1910	192,021	$10,422	1,205,916	$65,454
1911	248,899	12,638	839,732	42,638
1912	162,259	8,239	1,598,996	81,190
1913	46,076	2,824	1,258,827	77,142
1914	6,393	448	1,148,597	80,442
1915	441	37	2,612,671	217,288
1916	3,086	500	2,850,768	461,701
1917	----	----	2,205,923	357,264
1918	---	---	2,622,432	633,278
1919	2/	13	3,102,400	205,401
1920	6,720	252	1,921,920	68,602
1921	8,960	3/	2,271,360	3/
1922	2,240	93	1,720,320	151,975
1923	58,240	3/	3,624,320	3/
1924	96,320	3/	3,711,680	3/
1925	8,960	3/	3,704,960	3/
1926	8,960	3/	3,171,840	3/
1927	11,200	3/	3,032,960	3/
1928	4,480	3/	2,932,160	3/
1929	----	----	2,042,880	3/
1930	---	---	4/1,824,912	3/

1/ Data mainly from the Tariff Information Survey, A-1, and the Mineral Industry of the British Empire and Foreign Countries (Annual).
2/ Less than 1/2 ton.
3/ Value not reported.
4/ Estimated.

BORON

Borides, other than ferroboron, of which the qualities are not as yet fully determined, are used to a limited extent at present for the oxidation and degasification of molten metal. These borides are calcium boride (CaB_6), manganese-silicon boron, magnesium-calcium-copper boron (about 85 per cent of copper), and manganese boron (MnB_6). These boron alloys are used mostly in the nonferrous metal industries, principally in brass and bronze, and some of them are not suitable at all for use in the manufacture of steel.[31]

These products in common with ferroboron, zirconium boron, and other borides of even lesser application, are all made in electric furnaces. Like ferrotungsten, they can not be tapped molten; after each run the furnace has to be torn down, and whereas in the case of ferrotungsten the resulting button may weigh as much as 4 tons, in the case of these lighter and more difficultly

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31 - U. S. Tariff Commission, Summary of Tariff Information, 1929, On Tariff Act of 1922, Schedule 3, Metals and Manufacturers of, 1929, p. 622.

obtained alloys it seldom amounts to more than 300 pounds. Since the raw materials for these borides are relatively inexpensive, the chief item in production cost is the conversion charge.

Research on metallic boron and its alloys, primarily with a view of utilizing the element's electrical and fusing properties, have been made, particularly during the war. The uses developed so far for the element, while important, consume only relatively small quantities. Attempts have been made to utilize the electrical properties in various instruments, such as voltage regulators and automatic cut-outs, but without much commercial success.

Crystalline and amorphous boron are used in the manufacture of boron steels, for which certain special properties are claimed.

Boron and boron carbon are among the hardest artificial materials known, and it is expected that certain applications, such as the manufacture of bearings, will utilize this property. Several patents have been issued covering these wear-resisting alloys, such as U. S. 1,626,726, granted May 3, 1927 to B. E. Field and R. Franks. This particular patent is for an alloy suitable for making bearings, gages, or other articles which are subject to abrasive action. The alloy is comprised of iron with 1 to 12 per cent of tungsten, 25 to 35 per cent of chrome, 1.0 to 3.5 per cent of carbon, and 0.1 to 1.0 per cent of boron. Experiments in France indicate that remarkably strong steel can be made using 0.5 to 2 per cent of boron; its action was claimed to be much like that of vanadium.

According to the "Metal Industry":[32]

> Grinding wheels, etc., are made from abrasive grains (crystalline alumina or silicon carbide) and a vitrified ceramic bond having the same coefficient of expansion as the grains at temperatures below the annealing range. The bond mixture is the same as other well-known bonds, with the exception that it contains 11.3 per cent boron oxide. (British patent 295,292.)

A list of patents on the extraction, manufacture, and use of boron compounds was published in 1927.[33]

Imports and Tariff

While ferroboron has been mentioned in various tariff acts in the past, it was not until 1925 that any imports of this material were separately recorded. Table 20 shows the imports for consumption, together with the rates of duty, of ferroboron into the United States for the years 1922 to 1929, inclusive.

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32 - Metal Industry (London), British Patents: Vol. 33, No. 16, Oct. 19, 1928, pp. 379-80.

33 - Worden, E. W., Chemical Patents Index: Chemical Catalog Co., Inc., New York, vol. 1, 1927, pp. 823-35.

Data as to imports of amorphous boron or boron alloys are not available.

Table 20.- Imports of ferroboron for consumption, and rates of duty[1]

Year	Rate of duty	Quantity, pounds	Value
1922 (Sept. 22-Dec. 31)	25 per cent	----	-----
1923	do.	----	-----
1924	do.	----	-----
1925	do.	130	$226
1926	do.	100	171
1927	do.	112	193
1928	do.	110	275
1929	do.		
1930			

1/ Summary of Tariff Information, 1929, on Tariff Act of 1922, Schedule 3, U. S. Government Printing Office, Washington, D.C.

Market and Prices[34]

With the exception of ferroboron, which is now being imported at the rate of about 100 to 125 pounds annually, the limited consumption of the boron alloys in the United States is supplied almost exclusively from domestic sources.

Among the cheaper of the boron alloys is magnesium-calcium-copper boron, which contains only 2 to 3 per cent of boron and sells for about $0.75 a pound. Calcium boride, which contains about 40 per cent of boron, costs from $1.75 to $2 per pound, while manganese-silicon boron, containing 25 per cent of boron, is intermediate in value, selling for from $1.10 to $1.50 a pound.

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[34] - U. S. Tariff Commission, Summary of Tariff Information: Schedule 1, 1929, p. 623.

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